BRITISH GAS

RESEARCH & TECHNOLOGY DIVISION

A SELECTION OF CONVERSION FACTORS

(Compiled primarily for use in the utilization fields of Research, Development and Testing)

British Gas

Revised 1992

Section 1
UNITS, CONVERSION FACTORS

Contents

Section 1

UNITS, CONVERSION FACTORS

1.1 UNITS

The system of units used in this Data Book is that recommended by the Gas Council (now the British Gas Corporation) and the Society of British Gas Industries (1). This system is "Le Système International d'Unités" (SI) with a few additions.

There are three classes of SI units

(a)	Base units (Table 1–1)	The seven base units on which SI is founded.
(b)	Supplementary units (Table 1–2)	These have not yet been classified as either base or derived units.
(c)	Derived units	These are expressed algebraically in terms of base units and/or supplementary units. Those derived units with special names and symbols are listed in Table 1–3.

The recommended prefixes for multiples and sub-multiples of SI units are shown in Table 1–4.

In Table 1–5 are listed those units of interest to the Gas Industry which, although not strictly part of SI, are of such practical importance that they may be used with SI.

In Section 1.2 factors are given for conversion between SI and various non-standard units. Factors are given to six significant figures except where stated otherwise. The values in the tables are based on conversion factors in BS 350 (2).

Those units whose names and symbols are framed in bold outline are recommended for use in the British Gas Industry. Reference is given in the tables to additional explanatory notes at the end of the section.

Full details of the SI and its use may be found in the relevant publications of the British Standards Institution (3, 4) and the National Physical Laboratory (5, 6).

TABLE 1–1

SI : Base Units

Quantity	Name	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
luminous intensity	candela	cd
amount of substance	mole	mol

TABLE 1–2

SI : Supplementary Units

Quantity	Name	Symbol
plane angle	radian	rad
solid angle	steradian	sr

TABLE 1–3

SI : Derived Units with Special Names

Quantity	Name	Symbol	Expression in terms of other units
frequency	hertz	Hz	s^{-1}
force	newton	N	$kg\ m/s^2$
pressure, stress	pascal	Pa	N/m^2
energy, work, quantity of heat	joule	J	N m
power	watt	W	J/s
electric charge, quantity of electricity	coulomb	C	A s
electric potential	volt	V	W/A
capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
conductance	siemens	S	A/V
magnetic flux	weber	Wb	V s
magnetic flux density	tesla	T	Wb/m^2
inductance	henry	H	Wb/A
luminous flux	lumen	lm	cd sr
illuminance	lux	lx	lm/m^2

TABLE 1–4

SI : Prefixes

Factor by which unit is multiplied	Name of prefix	Symbol	Factor by which unit is multiplied	Name of prefix	Symbol
10^{12}	tera	T	10^{-1}	deci	d
10^{9}	giga	G	10^{-2}	centi	c
10^{6}	mega	M	10^{-3}	milli	m
10^{3}	kilo	k	10^{-6}	micro	μ
10^{2}	hecto	h	10^{-9}	nano	n
10^{1}	deca	da	10^{-12}	pico	p
			10^{-15}	femto	f
			10^{-18}	atto	a

TABLE 1–5

Some other units in use with SI

Quantity	Unit	Symbol	Value
time	minute	min	60 s
	hour	h	60 min
	day	d	24 h
plane angle	degree	°	$(\pi/180)$ rad
	minute	′	$(1/60)°$
	second	″	$(1/60)′$
area	are	a	100 m^2
	hectare	ha	10 000 m^2
volume	litre	litre (l)	1 dm^3, 0.001 m^3
mass	tonne	tonne (t)	1000 kg
pressure	bar	bar	10^5 Pa
temperature	degree Celsius	°C	$t°C = (t + 273.15)$ K
temperature difference	degree Celsius	°C, degC	1 K

1.2 CONVERSION FACTORS

MASS

	kg	tonne	lb	UK ton	US ton
1 kilogram (kg)	1	0.001	2.204 62	$9.842\ 07 \times 10^{-4}$	$1.102\ 31 \times 10^{-3}$
1 tonne	1000	1	2204.62	0.984 207	1.102 31
1 pound (lb)	0.453 592	$4.535\ 92 \times 10^{-4}$	1	$4.464\ 29 \times 10^{-4}$	0.0005
1 UK ton (long ton)	1016.05	1.016 05	2240	1	1.12
1 US ton (short ton)	907.185	0.907 185	2000	0.892 857	1

	g	mg	lb	oz	gr
1 gram (g)	1	1000	$2.204\ 62 \times 10^{-3}$	0.035 274 0	15.4324
1 milligram (mg)	0.001	1	$2.204\ 62 \times 10^{-6}$	$3.527\ 40 \times 10^{-5}$	0.015 432 4
1 pound (lb)	453.592	$4.535\ 92 \times 10^{5}$	1	16	7000
1 ounce (oz)	28.3495	28 349.5	0.0625	1	437.5
1 grain (gr)	0.064 798 9	64.7989	$1.428\ 57 \times 10^{-4}$	$2.285\ 71 \times 10^{-3}$	1

1 hundredweight (cwt) = 112 lb = 50.8023 kg

AREA

	m^2	cm^2	mm^2	in^2	ft^2	yd^2
1 square metre (m^2)	1	10 000	10^6	1550.00	10.7639	1.195 99
1 square centimetre (cm^2)	10^{-4}	1	100	0.155 000	$1.076\ 39 \times 10^{-3}$	$1.195\ 99 \times 10^{-4}$
1 square millimetre (mm^2)	10^{-6}	0.01	1	$1.550\ 00 \times 10^{-3}$	$1.076\ 39 \times 10^{-5}$	$1.195\ 99 \times 10^{-6}$
1 square inch (in^2)	6.4516×10^{-4}	6.4516	645.16	1	$6.944\ 44 \times 10^{-3}$	$7.716\ 05 \times 10^{-4}$
1 square foot (ft^2)	0.092 903 0	929.030	92 903.0	144	1	0.111 111
1 square yard (yd^2)	0.836 127	8361.27	836 127	1296	9	1

	km^2	ha	a	yd^2	acre	$mile^2$
1 square kilometre (km^2)	1	100	10 000	$1.195\ 99 \times 10^6$	247.105	0.386 102
1 hectare (ha)	0.01	1	100	11 959.9	2.471 05	$3.861\ 02 \times 10^{-3}$
1 are (a)	10^{-4}	0.01	1	119.599	0.024 710 5	$3.861\ 02 \times 10^{-5}$
1 square yard (yd^2)	$8.361\ 27 \times 10^{-7}$	$8.361\ 27 \times 10^{-5}$	$8.361\ 27 \times 10^{-3}$	1	$2.066\ 12 \times 10^{-4}$	$3.228\ 31 \times 10^{-7}$
1 acre	$4.046\ 86 \times 10^{-3}$	0.404 686	40.4686	4840	1	1.5625×10^{-3}
1 square mile ($mile^2$)	2.589 99	258.999	25 899.9	$3.097\ 60 \times 10^6$	640	1

CAPACITY, VOLUME

(For volumes of gases at standard conditions, see Page 1.2/12)

	m^3	dm^3 [litre]	ft^3	UK gal	US gal	barrel
1 cubic metre (m^3)	1	1000	35.3147	219.969	264.172	6.289 80
1 cubic decimetre (dm^3) [litre] [1,4]	0.001	1	0.035 314 7	0.219 969	0.264 172	$6.289\ 80 \times 10^{-3}$
1 cubic foot (ft^3)	0.028 316 8	28.3168	1	6.228 84	7.480 52	0.178 107
1 Imperial gallon (UK gal)	$4.546\ 09 \times 10^{-3}$	4.546 09	0.160 544	1	1.200 95	0.028 593 9
1 U.S. gallon (US gal)	$3.785\ 41 \times 10^{-3}$	3.785 41	0.133 681	0.832 675	1	0.023 809 5
1 U.S. pet. barrel (barrel)	0.158 987	158.987	5.614 61	34.9724	42	1

	dm^3 [litre]	cm^3	$litre_{1901}$	UK gal	in^3	fl oz
1 cubic decimetre (dm^3) [litre] [4]	1	1000	0.999 972	0.219 969	61.0237	35.1951
1 cubic centimetre (cm^3)	0.001	1	$9.999\ 72 \times 10^{-4}$	$2.199\ 69 \times 10^{-4}$	0.061 023 7	0.035 195 1
1 litre, 1901 definition ($litre_{1901}$) [4]	1.000 03	1000.03	1	0.219 976	61.0255	35.1961
1 Imperial gallon (UK gal)	4.546 09	4546.09	4.545 96	1	277.419	160
1 cubic inch (in^3)	0.016 387 1	16.3871	0.016 386 6	$3.604\ 65 \times 10^{-3}$	1	0.576 744
1 fluid ounce (fl oz)	0.028 413 0	28.4130	0.028 412 2	$6.250\ 00 \times 10^{-3}$	1.733 87	1

1 pint (UK) = 0.125 UK gal = 0.568 261 dm^3

DENSITY

	kg/m^3	g/cm^3	lb/ft^3	lb/UK gal	lb/US gal
1 kilogram per cubic metre (kg/m^3)	1	0.001	0.062 428 0	0.010 022 4	$8.345\ 40 \times 10^{-3}$
1 gram per cubic centimetre (g/cm^3) [2]	1000	1	62.428 0	10.022 4	8.345 40
1 pound per cubic foot (lb/ft^3)	16.0185	0.016 018 5	1	0.160 544	0.133 681
1 pound per UK gallon (lb/UK gal)	99.7764	0.099 776 4	6.228 84	1	0.832 675
1 pound per US gallon (lb/US gal)	119.826	0.119 826	7.480 52	1.200 95	1

CONCENTRATION

In liquids: 1 gram per litre (g/litre) = 0.160 359 ounce per UK gallon (oz/UK gal)

In gases: 1 mg/m^3 (st) = 0.061 252 lb/(10^6 std. ft^3) *5*

1 mg/m^3 (st) = 0.042 876 grain/(100 std. ft^3) *5*

MASS/UNIT AREA

1 kg/m^2 = 0.204 816 lb/ft^2 1 lb/ft^2 = 4.882 43 kg/m^2

MASS/UNIT LENGTH

1 kg/m = 0.671 969 lb/ft 1 lb/ft = 1.488 16 kg/m

FORCE

	N	kN	kgf	lbf	pdl	tonf
1 newton (N)	1	0.001	0.101 972	0.224 809	7.233 01	$1.003\ 61 \times 10^{-4}$
1 kilonewton (kN)	1000	1	101.972	224.809	7233.01	0.100 361
1 kilogram-force (kgf)	9.806 65	$9.806\ 65 \times 10^{-3}$	1	2.204 62	70.9316	$9.842\ 07 \times 10^{-4}$
1 pound-force (lbf)	4.448 22	$4.448\ 22 \times 10^{-3}$	0.453 592	1	32.1740	$4.464\ 29 \times 10^{-4}$
1 poundal (pdl)	0.138 255	$1.382\ 55 \times 10^{-4}$	0.014 098 1	0.031 081 0	1	$1.387\ 54 \times 10^{-5}$
1 UK ton-force (tonf)	9964.02	9.964 02	1016.05	2240	72 069.9	1

$1\ N = 10^5$ dyn

VELOCITY

	m/s	cm/s	mm/s	km/h	ft/s	mile/h
1 metre per second (m/s)	1	100	1000	3.6	3.280 84	2.236 94
1 centimetre per second (cm/s)	0.01	1	10	0.036	0.032 808 4	0.022 369
1 millimetre per second (mm/s)	0.001	0.1	1	0.0036	$3.280\ 84 \times 10^{-3}$	$2.236\ 94 \times 10^{-3}$
1 kilometre per hour (km/h) [1]	0.277 778	27.7778	277.778	1	0.911 344	0.621 371
1 foot per second (ft/s)	0.3048	30.48	304.8	1.097 28	1	0.681 818
1 mile per hour (mile/h)	0.447 04	44.704	447.04	1.609 34	1.466 67	1

MOMENTUM

1 kg m/s = 7.233 01 lb ft/s 1 lb ft^2/s = 0.042 140 1 kg m^2/s

ANGULAR MOMENTUM

1 kg m^2/s = 23.7304 lb ft^2/s 1 lb ft^2/s = 0.042 140 1 kg m^2/s

PRESSURE, STRESS

	Pa	bar	atm	mmHg	kgf/cm^2	lbf/in^2
1 pascal (Pa) N/m^2	1	10^{-5}	$9.869\ 23 \times 10^{-6}$	$7.500\ 62 \times 10^{-3}$	$1.019\ 72 \times 10^{-5}$	$1.450\ 38 \times 10^{-4}$
1 bar [6]	10^5	1	0.986 923	750.062	1.019 72	14.5038
1 standard atmosphere (atm)	$1.013\ 25 \times 10^5$	1.013 25	1	760	1.033 23	14.6959
1 millimetre of mercury (mmHg)	133.322	$1.333\ 22 \times 10^{-3}$	$1.315\ 79 \times 10^{-3}$	1	$1.359\ 51 \times 10^{-3}$	0.019 336 8
1 kgf/cm^2	$9.806\ 65 \times 10^4$	0.980 665	0.967 841	735.559	1	14.2233
1 lbf/in^2 (psi)	6894.76	0.068 947 6	0.068 046 0	51.7149	0.070 307 0	1

	mbar	mmHg	inHg	inH_20	mmH_20	lbf/in^2
1 millibar (mbar) [6]	1	0.750 062	0.029 530 0	0.401 463	10.1972	0.014 503 8
1 mmHg	1.333 22	1	0.039 370 1	0.535 240	13.5951	0.019 336 8
1 inch of mercury, (inHg)	33.8639	25.4	1	13.5951	345.316	0.491 154
1 inch of water, (inH_20)	2.490 89	1.868 32	0.073 555 9	1	25.4	0.036 127 3
1 millimetre of water, (mmH_20)	0.098 066 5	0.073 555 9	$2.895\ 90 \times 10^{-3}$	0.039 370 1	1	$1.422\ 33 \times 10^{-3}$
1 lbf/in^2	68.9476	51.7149	2.036 02	27.6799	703.070	1

1 $tonf/in^2$ = 2240 lbf/in^2 = 15.4443 MN/m^2 = 15.4443 N/mm^2

1 dyn/cm^2 = 0.1 Pa

FLOW RATE (MASS)

	kg/s	kg/h	lb/s	lb/h	ton/h	ton/day
1 kilogram per second (kg/s)	1	3600	2.204 62	7936.64	3.543 14	85.0354
1 kilogram per hour (kg/h) [1]	$2.777\ 78 \times 10^{-4}$	1	$6.123\ 95 \times 10^{-4}$	2.204 62	$9.842\ 07 \times 10^{-4}$	0.023 621 0
1 pound per second (lb/s)	0.453 592	1632.93	1	3600	1.607 14	38.5714
1 pound per hour (lb/h)	$1.259\ 98 \times 10^{-4}$	0.453 592	$2.777\ 78 \times 10^{-4}$	1	$4.464\ 29 \times 10^{-4}$	0.010 714 3
1 UK ton per hour (ton/h)	0.282 235	1016.05	0.622 222	2240	1	24
1 UK ton per day (ton/day)	0.011 759 80	42.3353	0.025 925 9	93.3333	0.041 666 7	1

FLOW RATE (VOLUMETRIC)

	m^3/h	litre/h	ft^3/min	ft^3/h	UK gal/min	UK gal/h
1 cubic metre per hour (m^3/h) [1]	1	1000	0.588 578	35.3147	3.666 16	219.969
1 litre per hour (litre/h) [1,4]	0.001	1	$5.885\ 78 \times 10^{-4}$	0.035 314 7	$3.666\ 16 \times 10^{-3}$	0.219 969
1 cubic foot per minute (ft^3/min)	1.699 01	1699.02	1	60	6.228 84	373.730
1 cubic foot per hour (ft^3/h)	0.028 316 8	28.3168	0.016 666 7	1	0.103 814	6.228 84
1 UK gallon per minute (UK gal/min)	0.272 765	272.765	0.160 544	9.632 63	1	60
1 UK gallon per hour (UK gal/h)	$4.546\ 09 \times 10^{-3}$	4.546 09	$2.675\ 73 \times 10^{-3}$	0.160 544	0.016 666 7	1

1 m^3 (st)/h = 35.993 std.ft^3 /h [5] 1 std.ft^3 /h = 0.027 784 m^3 (st)/h [5]

1 m^3(st)/h = 0.863 82 thousand std.ft^3/day (mscf/d) [5]

1 litre/h = 0.150 96 million US barrels/day (mmbarrel/d)

VISCOSITY (DYNAMIC)

	Pa s	P	cP	μP	lb/(ft s)	lbf s/ft^2
1 Pa s (kg/(m s))	1	10	1000	10^7	0.671 969	0.020 885 4
1 poise (P)[7]	0.1	1	100	10^6	0.067 196 9	$2.088\ 54 \times 10^{-3}$
1 centipoise (cP)(g/(m s))[7]	0.001	0.01	1	10^4	$6.719\ 69 \times 10^{-4}$	$2.088\ 54 \times 10^{-5}$
1 micropoise (μP)[7]	10^{-7}	10^{-6}	10^{-4}	1	$6.719\ 69 \times 10^{-8}$	$2.088\ 54 \times 10^{-9}$
1 lb/(ft s)	1.488 16	14.881 6	1488.16	$1.488\ 16 \times 10^7$	1	0.031 081 0
1 lbf s/ft^2	47.8803	478.803	$4.788\ 03 \times 10^4$	$4.788\ 03 \times 10^8$	32.1740	1

1 lb/(ft h) = 0.413 378 cP

VISCOSITY (KINEMATIC)

	m^2/s	St	cSt	in^2/s	ft^2/h
1 m^2/s	1	10^4	10^6	1550.00	$3.875\ 01 \times 10^4$
1 stokes (St) (cm^2/s)[7]	10^{-4}	1	100	0.155 000	3.875 01
1 centistokes (cSt) (mm^2/s)[7]	10^{-6}	0.01	1	$1.550\ 00 \times 10^{-3}$	0.038 750 1
1 in^2/s	6.4516×10^{-4}	6.4516	645.16	1	25
1 ft^2/h	$2.580\ 64 \times 10^{-5}$	0.258 064	25.8064	0.04	1

HEAT, WORK, ENERGY

	J	cal_{IT}	$kcal_{IT}$	Btu_{IT}	ft lbf	ft pdl
1 joule (J)	1	0.238 846	$2.388\ 46 \times 10^{-4}$	$9.478\ 17 \times 10^{-4}$	0.737 562	23.7304
1 calorie [I.T.] (cal_{IT})	4.1868	1	0.001	$3.968\ 32 \times 10^{-3}$	3.088 03	99.3544
1 kilocalorie [I.T.] ($kcal_{IT}$)	4186.8	1000	1	3.968 32	3088.03	99 354.4
1 British thermal unit [I.T.] (Btu_{IT}) [8]	1055.06	251.996	0.251 996	1	778.169	25 036.8
1 foot pound-force (ft lbf)	1.355 82	0.323 832	$3.238\ 32 \times 10^{-4}$	$1.285\ 07 \times 10^{-3}$	1	32.1740
1 foot poundal (ft pdl)	0.042 140 1	0.010 065 0	$1.006\ 50 \times 10^{-5}$	$3.994\ 12 \times 10^{-5}$	0.031 081 0	1

	MJ	Btu_{IT}	therm	th	kW h	hp h
1 megajoule (MJ)	1	947.817	$9.478\ 17 \times 10^{-3}$	0.238 920	0.277 778	0.372 506
1 Btu_{IT} [8]	$1.055\ 06 \times 10^{-3}$	1	10^{-5}	$2.520\ 74 \times 10^{-4}$	$2.930\ 71 \times 10^{-4}$	$3.930\ 15 \times 10^{-4}$
1 therm	105.506	10^5	1	25.2074	29.3071	39.3015
1 thermie (th)	4.1855	3967.09	0.039 670 9	1	1.162 64	1.559 12
1 kilowatt hour (kW h)	3.6	3412.14	0.034 121 4	0.860 112	1	1.341 02
1 horsepower hour (hp h)	2.684 52	2544.43	0.025 444 3	0.641 386	0.745 700	1

1 calorie (15°) = 4.1855 J 1 calorie (thermochemical) = 4.184 J

1 $Btu_{15°}$ = 0.999 69 Btu_{IT} = 1054.73 J [8]

1 thermie = 10^6 $cal_{15°}$

1 erg = 10^{-7} J

CALORIFIC VALUE (PER UNIT MASS), SPECIFIC LATENT HEAT

	kJ/kg	MJ/kg	cal_{IT}/g	Btu_{IT}/lb	kW h/kg
1 kilojoule per kilogram (kJ/kg)	1	0.001	0.238 846	0.429 923	$2.777\,78 \times 10^{-4}$
1 megajoule per kilogram (MJ/kg)	1000	1	238.846	429.923	0.277 778
1 calorie (I.T.) per gram (cal_{IT}/g)	4.1868	4.1868×10^{-3}	1	1.8	1.163×10^{-3}
8 1 Btu (I.T.) per pound (Btu_{IT}/lb)	2.326	2.326×10^{-3}	0.555 556	1	$6.461\,11 \times 10^{-4}$
1 kilowatt hour per kilogram (kW h/kg)	3600	3.6	859.845	1547.72	1

CALORIFIC VALUE (PER UNIT VOLUME)

(For values with reference to volumes of gases at standard conditions, see Page 1.2/13)

	MJ/m^3	cal_{IT}/cm^3	th/litre	Btu_{IT}/ft^3	therm/UK gal
1 MJ/m^3	1	0.238 846	$2.389\,20 \times 10^{-4}$	26.8392	$4.308\,86 \times 10^{-5}$
1 cal_{IT}/cm^3	4.1868	1	$1.000\,31 \times 10^{-3}$	112.370	$1.804\,03 \times 10^{-4}$
4 1 thermie per litre (th/litre)	4185.50	999.690	1	$1.123\,35 \times 10^{5}$	0.180 348
8 1 Btu_{IT}/ft^3	0.037 258 9	$8.899\,15 \times 10^{-3}$	$8.901\,91 \times 10^{-6}$	1	$1.605\,44 \times 10^{-6}$
1 therm/UK gal	$2.320\,80 \times 10^{4}$	5543.14	5.544 86	$6.228\,84 \times 10^{5}$	1

1 GJ/m^3 = 1000 MJ/m^3

VOLUMES OF GASES AT STANDARD CONDITIONS

	m^3(st) dry	m^3(NTP) dry	ft^3(ISC) dry	ft^3(ISC) sat	ft^3 (Int.) dry	ft^3(NTP) dry
1 m^3(st) dry	1	0.947 94	35.366	35.993	35.290	33.476
1 m^3(NTP) dry	1.0549	1	37.308	37.969	37.228	35.315
1 ft^3(ISC) dry	0.028 276	0.026 804	1	1.0177	0.997 85	0.946 58
1 ft^3(ISC) sat	0.027 784	0.026 337	0.982 58	1	0.980 47	0.930 09
1 ft^3(Int.) dry	0.028 337	0.026 862	1.0022	1.0199	1	0.948 61
1 ft^3(NTP) dry	0.029 872	0.028 317	1.0564	1.0752	1.0542	1

m^3(st) : Metric Standard Conditions

The cubic metre is measured at a temperature of 15°C and a pressure of 1013.25 mbar (1 atm), dry.

ft^3(ISC) : Imperial Standard Conditions

The cubic foot is measured at a temperature of 60°F and a pressure of 30 inches Hg. The mercury column is at 60°F and subjected to average gravity at a latitude of 53°N. This pressure is equal to 1013.74 mbar.

ft^3(Int.) : "International" Cubic Foot

The cubic foot is measured at a temperature of 60°F and a pressure of 30 inches Hg. The mercury column is at 32°F (0°C) and subjected to standard gravity (9.806 65 m/s^2). This pressure is equal to 1015.92 mbar (14.73 lbf/in^2).

ft^3(NTP), m^3(NTP): Normal Temperature and Pressure

The cubic foot (or metre) is measured at a temperature of 0°C and a pressure of 1013.25 mbar (1 atm).

CALORIFIC VALUE (FOR GASES AT STANDARD CONDITIONS)

	MJ/m^3(st) dry	$kcal_{IT}$/ m^3 (NTP) dry	$Btu_{15°}$/ ft^3 (ISC) dry	$Btu_{15°}$/ ft^3 (ISC) sat	Btu_{IT}/ ft^3 (Int.) dry
1 MJ/m^3(st) dry	1	251.9	26.81	26.34	26.86
1 $kcal_{IT}/m^3$ (NTP) dry	3.97×10^{-3}	1	0.1064	0.1046	0.1066
1 $Btu_{15°}/ft^3$ (ISC) dry [8]	0.037 30	9.397	1	0.982 58	1.0018
1 $Btu_{15°}/ft^3$ (ISC) sat [8]	0.037 96	9.564	1.0177	1	1.0196
1 Btu_{IT}/ft^3 (Int.) dry [8]	0.037 23	9.380	0.998 16	0.980 78	1

Note: The factors for conversion between the units of MJ/m^3(st), Btu/ft^3, and $kcal_{IT}/m^3$(NTP) are only approximate: these units have different reference temperatures for the heat of combustion and hence the conversion factors depend on the composition of the gas.

(See page 1.2/12 for specifications of the conditions under which the standard volumes are measured.)

POWER, HEAT FLOW RATE

	W	kW	MJ/h	Btu_{IT}/h	ft lbf/s	hp
1 watt (W)	1	0.001	0.0036	3.412 14	0.737 562	$1.341\ 02 \times 10^{-3}$
1 kilowatt (kW)	1000	1	3.6	3412.14	737.562	1.341 02
1 megajoule per hour (MJ/h) [9]	277.778	0.277 778	1	947.817	204.878	0.372 506
1 Btu_{IT} per hour (Btu_{IT}/h) [8]	0.293 071	$2.930\ 71 \times 10^{-4}$	$1.055\ 06 \times 10^{-3}$	1	0.216 158	$3.930\ 15 \times 10^{-4}$
1 foot pound-force per second (ft lbf/s)	1.355 82	$1.355\ 82 \times 10^{-3}$	$4.880\ 95 \times 10^{-3}$	4.626 24	1	$1.818\ 18 \times 10^{-3}$
1 UK horsepower (hp)	745.700	0.745 700	2.684 52	2544.43	550	1

1 metric horsepower = 0.986 320 UK hp = 735.500 W

1 $kcal_{IT}$/hour = 1.163 W

SPECIFIC HEAT CAPACITY, SPECIFIC ENTROPY

	J/(kg °C)	kJ/(kg °C)	$cal_{IT}/(g\ °C)$	$Btu_{IT}/(lb\ °F)$
1 J/(kg °C)	1	0.001	$2.388\ 46 \times 10^{-4}$	$2.388\ 46 \times 10^{-4}$
1 kJ/(kg °C)	1000	1	0.238 846	0.238 846
1 $cal_{IT}/(g\ °C)$	4186.8	4.1868	1	1
1 $Btu_{IT}/(lb\ °F)$ [8]	4186.8	4.1868	1	1

THERMAL CONDUCTIVITY

	W/(m °C)	W/(cm °C)	$kcal_{IT}$/(m h °C)	cal_{IT}/(cm s °C)	Btu_{IT}/(ft h °F)	Btu_{IT} in/(ft^2 h °F)
1 W/(m °C)	1	0.01	0.859 845	$2.388\ 46 \times 10^{-3}$	0.577 789	6.933 47
1 W/(cm °C)	100	1	85.9845	0.238 846	57.7789	693.347
1 $kcal_{IT}$/(m h °C)	1.163	0.011 63	1	$2.777\ 78 \times 10^{-3}$	0.671 969	8.063 63
1 cal_{IT}/(cm s °C) [8]	418.68	4.1868	360	1	241.909	2902.91
1 Btu_{IT}/(ft h °F) [8]	1.730 73	0.017 307 3	1.488 16	$4.133\ 79 \times 10^{-3}$	1	12
1 Btu_{IT} in/(ft^2 h °F)	0.144 228	$1.442\ 28 \times 10^{-3}$	0.124 014	$3.444\ 82 \times 10^{-4}$	0.083 333 3	1

HEAT TRANSFER COEFFICIENT (THERMAL CONDUCTANCE)

	W/(m^2 °C)	kW/(m^2 °C)	W/(cm^2 °C)	cal_{IT}/(cm^2 s °C)	$kcal_{IT}$/(m^2 h °C)	Btu_{IT}/(ft^2 h °F)
1 W/(m^2 °C)	1	0.001	10^{-4}	$2.388\ 46 \times 10^{-5}$	0.859 845	0.176 110
1 kW/ (m^2 °C)	1000	1	0.1	0.023 884 6	859.845	176.110
1 W/(cm^2 °C)	10^4	10	1	0.238 846	8598.45	1761.10
1 cal_{IT}/(cm^2 s °C)	4.1868×10^4	41.868	4.1868	1	3.6×10^4	7373.38
1 $kcal_{IT}$/(m^2 h °C)	1.163	1.163×10^{-3}	1.163×10^{-4}	$2.777\ 78 \times 10^{-5}$	1	0.204 816
1 Btu_{IT}/(ft^2 h °F) [8]	5.678 26	$5.678\ 26 \times 10^{-3}$	$5.678\ 26 \times 10^{-4}$	$1.356\ 23 \times 10^{-4}$	4.882 43	1

TEMPERATURE

T K, t °C, T °R and t °F represent the same temperature on the Kelvin, Celsius, Rankine and Fahrenheit scales respectively..

$$T\,K = \{T - 273.15\}\ °C = \left\{\frac{9}{5}T\right\}\ °R = \left\{\frac{9}{5}T - 459.67\right\}\ °F$$

$$t\,°C = \{t + 273.15\}\ K = \left\{\frac{9}{5}(t + 273.15)\right\}\ °R = \left\{\frac{9}{5}t + 32\right\}\ °F$$

$$T\,°R = \left\{\frac{5}{9}T\right\}\ K = \left\{\frac{5}{9}T - 273.15\right\}\ °C = \{T - 459.67\}\ °F$$

$$t\,°F = \left\{\frac{5}{9}(t + 459.67)\right\}\ K = \left\{\frac{5}{9}(t - 32)\right\}\ °C = \{t + 459.67\}\ °R$$

THE UNIVERSAL GAS CONSTANT

Numerical Value	Units
8.314 34	J/(mol K)
1.985 85	Btu_{IT}/(lb–mole °R)
0.083 143 4	bar m^3/(kmol K)
82.0562	atm cm^3/(mol K)
0.082 056 2	atm litre/(mol K)
10.7315	ft^3 lbf/(in^2 lb-mole °R)

QUANTITY OF SUBSTANCE

1 kilomole (kmol)	=	1000 mole (mol)
1 mol	=	2.204 62 x 10^{-3} lb-mole
1 lb-mole	=	453.592 mol

NOTES

1. The units tonne, litre (see also note 4), minute, hour and day are not strictly part of SI, but are recognized by the International Committee of Weights and Measures (CIPM) as having such importance that they must be retained for general use.

2. In science and engineering centi– is not a recommended prefix for SI units, but the centimetre, square centimetre and cubic centimetre may be used if convenient for general purposes.

3. The are and hectare are non–SI units that are recommended for use in the Gas Industry to denote land areas.

4. The definition of the litre proposed in 1901 is no longer valid, and the word "litre" may now be employed as a special name for the cubic decimetre. However, the name litre should not be used for the results of highly accurate measurements of volume. In these tables, litres appearing in derived units refer to the new litre (1 dm^3).

5. The units m^3(st) and std. ft^3 denote volumes of gas at metric standard reference conditions and Imperial standard conditions (ISC) respectively,

   m^3(st) ..... 15°C, 1013.25 mbar, dry

   std. ft^3 ..... 60°F, 30 inches Hg (@ 60°F, latitude 53°N), saturated

6. The bar and millibar are non–SI units of pressure adopted by the I.G.U. and recommended for use in the Gas Industry. It should always be indicated whether a stated pressure is absolute, gauge or vacuum. For an absolute pressure of P mbar,

   gauge pressure = (P – 1013.25) mbar

   vacuum = (1013.25 – P) mbar

7. The poise and the stokes, together with their sub-multiples, are non–SI units of viscosity that are widely used with SI and are recommended for use in the Gas Industry.

8. Two definitions of the British Thermal Unit are in use in the Gas Industry. That defined by the Controller of Gas Standards is the $Btu_{15°}$, which is based on the 15° calorie ($cal_{15°}$), and is the quantity of heat necessary to raise the temperature of 1 lb of water at 15°C by 1°F. In contracts the British Gas Corporation uses the International Table Btu (Btu_{IT}), which is based on the International Table calorie (cal_{IT}), and is equal to 1055.056 J.

   For calorific values, the $Btu_{15°}$ is used in conjunction with the ft^3 (ISC), and the Btu_{IT} with the ft^3(Int.): see page 1.2/13

9. The kilowatt, which is an SI unit, is to be used for appliance inputs and/or outputs, but megajoules per hour (MJ/h) may conveniently be used for the calculation of running costs, etc., and where appropriate should be quoted in brackets after the value in kilowatts.

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(1) "SI Units and Conversion Factors for use in the British Gas Industry", Gas Council and Society of British Gas Industries, Revised 1972.

(2) "Conversion Factors and Tables", British Standards Institution, B.S. 350: Part 1 : 1959.

(3) "The International System of Units (SI)", British Standards Institution, B.S. 3763 : 1970.

(4) "The Use of SI Units", British Standards Institution, PD 5686 : 1972.

(5) "SI – The International System of Units", National Physical Laboratory; HMSO, 1970.

(6) "Changing to the metric system. Conversion factors, symbols and definitions", National Physical Laboratory; HMSO, 1969.

COMPARISONS

Flow: 6000 sm^3/hr nat.gas, 15°C, 35bara, SG=0.587, .012cP, 250mbarDP, 3"pipe, Z@p=.925454, Z@std=.9978, cP/cV=1.316

	ESI	Orif3	Orif4	ISA
standard P	14.730 psia	1.01325 mbar	-..-	14.700 psia
standard T	60°F	15°C	-..-	60°F
m^3/kgmol	?	23.645 [1]	-..-	23.684
MW (calc)	-	16.971423 [2]	-..-	-
Weight/hr	-	4316.2109	-..-	4307.18 [3]
Density @P	-	26.790878 [4]	-..-	26.84587
Beta ratio	.6400171	-	.61067	.60972
Bore, mm	47.1437	-	44.982	44.913

[1] This is what should be used in the BG programs.
[2] 28.9641 x .587 = 17.002
[3] None use the Z@std, so all too low.
[4] BG includes Z@std, should not, so too low.

BASE DATA

A, **Gas Volumes:**

Starting from the standard 22.4140 m^3/kgmol (22.4136 l/gmol) the standard gas volumes are:-

1. sm3/hr at 15°C, 1013.25 mbar (760.0 mmHg, 14.696 psia)
   = 23.645 m^3/kgmol (378.76 ft^3/lbmol)

2. scfh(*) at 60°F, (1013.53 mbar, 760.2 mmHg), 14.700 psia
   = 23.684 m^3/kgmol (379.39 ft^3/lbmol)

3. scfh(ISC) at 60°F, (1013.74 mbar) 30 "Hg (14.703 psia)
   = 23.679 m^3/kgmol (379.31 ft^3/lbmol)

4. scfh(Int) at 60°F, (1015.92 mbar, 30 "Hg*), 14.730 psia
   = 23.630 m^3/kgmol (378.56 ft^3/lbmol)

NOTE: BG data book defines scfh(Int) at 30"Hg @0°C & g / 1015.92 mbar and then rounds to 14.73 psia. American programs are based on 14.730 psia and so quote 1015.597 mbar as the metric pressure.

BG normally use 1 for sm^3/hr and used to use 3 (wet) for scfh, however some commercial programs are based on 2 for both Metric and Imperial. American based programs tend to use 4.

B, **Molecular Weight of Air:**.

The international standard is: 28.964 1 for dry air.

.0783 32

R= 0.083143

TO CONVERT FROM:	MULTIPLY BY FACTOR TO OBTAIN:						
	MJ	kcal	kWh	CHU	Btu	hph	ft lbf
MJ	1	238.8	0.2778	526.6	947.8	0.3725	7.376E+005
kcal	0.00419	1	0.001163	2.205	3.968	0.00156	3088
kWh	3.6	859.8	1	1896	3412	1.341	2.655E+006
CHU	0.00189897	0.4535	5.274E-004	1	1.8	7.074E-004	1401
Btu	0.001055	0.2520	2.931E-004	0.5556	1	3.930E-004	778.2
hph	2.685	641.0	0.7457	1414	2545	1	1.980E+006
ft lbf	1.356E-006	3.238E-004	3.766E-007	7.138E-004	0.00128502	0.00000051	1
therm	105.506	25199.6	29.3071	55550	100000	39.3015	7.782E+007